Common Carp and the Cherokee Marsh:

Population and Biomass Estimate for Evaluation of Management Strategies

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INTRODUCTION

This report provides a population estimate, size and age distribution, length –weight relationship, biomass estimate, and growth model for common carp (*Cyprinus carpio*) in Lake Cherokee (WBIC 806500) derived from a November 7 , 2013 marking and November 26, 2013 recapture effort.

Since the dredging of Lake Cherokee in 1962, the Yahara estuary above STH 113 has experienced significant habitat loss. Changes to the river channel include significant widening, shoreline erosion, sediment deposition, and loss of aquatic macrophtyes. Soluble phosphorus moving from the estuary into downstream Lake Mendota contributes to nuisance algal blooms.

This project was a cooperative effort with Dane County Land Conservation, The University of Wisconsin College of Engineering, and the Friends of Cherokee Marsh. Partners worked under the hypothesis that bio-turbation by carp contributes to habitat loss and phosphorus re-suspension through destabilizing lake bed sediment. The resulting turbidity prevents plant growth and thereby potential of aquatic plants to dissipate wind and wave energy. Carp removal in Lake Cherokee may contribute to improvement in water quality in both Lake Cherokee and Lake Mendota at an acceptable cost and timeframe.

It was necessary to quantify the carp population and biomass in the lake to calculate what phosphorous delivery might be mitigated by the removal of carp. This required performing a mark and recapture population estimate, during which a sub-sample was measured and weighed to estimate the carp population biological parameters.

In late fall 2013, the fisherman who held the rough fish removal contract was hired to conduct seining operations that served to provide the marked sample. Then, catches from routine fishing were monitored for marked fish to estimate population size and calculate a biomass estimate.

METHODS

Initial collection of marked sample

A 3000’ seine haul, consisting of 6-7 inch mesh, was begun on Monday Nov 4, 2013. The net was deployed from the east bank, thence north- westerly toward the upriver end of the central lake basin. The arced path of deployment encircled fish that had been scouted the previous day. While located by sight from surface disturbance, the observed schooling was supported by telemetry. The net was then pulled from west to east with the catch condensed into a temporary mesh holding pen located in the shallows off the east bank.

On Thurs Nov 7, WI DNR fisheries staff processed randomly sub-sampled fish from the seine haul. Fish were given a left pectoral (LP) clip, measured, and returned to the water as the marked sample (M). A smaller sub- sample was stratified by one inch length bins and weighed to define the length –weight relationship. Lengths were recorded to the 0.1 inch and weights to 0.1 lb. We attempted to voucher 5 fish per 1 inch length class for age determination from otoliths and dorsal spines. The fisherman estimated the entire catch at 6000pounds big mouth buffalo (*Ictiobus cyprinellus)* and 15,000 pounds carp. The remaining fish escaped after the marking effort due to wind and wave action that compromised the holding pen before sale and harvest occurred.

Recapture collection

After a 2.5 week re-mixing period, a recapture seining effort occurred on Nov 26, 2013. Netting occurred in the same location and under the same protocol as the initial earlier marking effort. Once again, captured fish were held in a net enclosure and allowed to mix freely. A second holding pen was established and fish randomly removed from the first pen were inspected for clips, counted, and placed into the second pen. The fisherman then harvested and marketed the entire catch.

Aging structures

Dorsal spines and otoliths were sampled from 83 fish that were vouchered to obtain 5 fish per 1 inch length class from 13 to 32 inches in length. Otoliths were embedded in an epoxy mold (Bedford Institute of Oceanography 2014) and sectioned through the nucleus by cutting on a Buhler low speed Isomet saw equipped with a diamond blade. Spines were cast into epoxy using micro-centrifuge tubes to allow thin sectioning (Koch and Quist, 2007) of a 1.10 mm thick cross section. Sectioned samples were wet sanded on 600 grit paper, mounted with clear adhesive on microscope slides, photographed, and annuli enumerated using Nikon Elements software.

Images were viewed independently by readers and ages were assigned using a double blind reading technique. Original age estimates were compared and later readers viewed the images together and resolved differences in age (Buckmeier 2002). Upon completion of finalized age estimation data analysis was performed.

Data analysis: length- weight, population size, biomass

The length-weight relationship was described using the standard formula (Nielson and Johnson, 1983):

$$\log_{10}(W_s) = a + b * \log_{10}(\text{Total Length})$$

Where: W_s = Standard weight, a = intercept, b = line slope

The standard weight formula was then applied to the entire sample of measured fish. This total predicted weight, divided by the total number of individuals measured, determined a predicted average weight per individual. The average weight was then used to predict the total number of fish removed during the recapture process per:

Number of fish removed = Total weight at market ÷ average weight per individual.

The population estimate was generated using a single census Chapman estimate:

$$N = \frac{(M+1) \times (C+1)}{(R+1)} - 1$$

Where:
N = estimate
M = marked first sample
C = caught 2nd sample
R = Recaptured (bearing marks) 2nd sample

Total biomass of common carp in Cherokee Lake prior to removal was estimated as:

Initial biomass = population estimate ×average weight.

Remaining biomass (post harvest) was estimated as:

Remaining biomass= initial biomass- total weight at market.

Data analysis – age sample and growth

An age –length key was constructed by applying the observed percentages of age at length from the aged subsample lengths to the population sample of lengths, (Devries and Frie 1996).

A Von Bertalanffy growth model was used to describe the relationship between length and age and to compare the fit of observed lengths at age to predicted values from both otolith and dorsal spine derived ages. The model is :

$$\boldsymbol{L_t} = \boldsymbol{L_\infty} \ (1-e^{(-K(t-t_0))})$$

Where:

$\boldsymbol{L_t}$ = length at age t
$\boldsymbol{L_\infty}$ = theoretical maximum length (asymptotic)
K = growth coefficient, proportional to rate at which L_∞ is reached
t_0 = theoretical age at L = 0

The Von Bertalanffy growth model was fit to the data using an iterative model fitting process (Isely and Grabowski, 2007) in Excel software. Carp in their known first year of growth and with observed lengths were assigned age 0+ .

RESULTS

Commercial Seining and Removal -2013

From the initial November 7, 2013 netting 2039 randomly selected carp were withdrawn from the holding pen. Of these, 1956 were fin clipped and released back into Cherokee lake. Lengths and weights were collected on 142 fish. Additionally 83 of the 142 fish between 13 and 32 inches in length were vouchered for otolith and dorsal spine removal to determine age.

The second netting of November 26, 2013 allowed for inspection of a subsample (N = 5583) of random fish drawn from the total catch for recovery of marks (LP clips). Market weights from the second netting reported from sales by the commercial fisherman were 44,500 lbs. of carp removed.

Population Estimate

The input variables used in the Chapman modification of the Peterson population estimate were; (M) = 1956, (C) = 5583 and (R) = 121. The point population estimate was calculated at 89,572 carp with lower and upper limits of 75,222 and 107,578 respectively. The coefficient of variation was 8.9 %.

Length frequency

The length frequency distribution of carp is given in Figure 2. Carp < 14 inches were not vulnerable to gear and not represented. Lengths ranged from 13.5” to 32.5 inches with an average length of 20.76 inches. The distribution is bi-modal with peaks at 16 and 22 inches.

Length Weight Relationship

The observed length –weight relation is shown in Figure 3. Length and weight were strongly correlated, Figure 4.,with a linear model fit to the log-transformed data ($y = 2.9x - 3.3$: $R^2 = 0.9747$). Predicted weights ranged from 1.15 lbs. to 15.65 lbs. with an average of 4.47 lbs.

Biomass estimate

Using the population estimate of 89,572 and the modeled average weight of 4.47 lbs, the estimate of carp biomass is 400,386 lbs. At approximately 390 acres, the Cherokee lake-Yahara estuary biomass of carp is 1027 lbs./acre.

Exploitation and weight

The second netting resulted in 44,500 lbs. of carp being marketed. The calculated average weight of 4.47 pounds converts to a removal of 9,555 fish or 10.6 % of the estimated population. By weight, this represents an 11.1% removal of the estimated carp biomass. Table 1. documents the commercial fishing removals from Cherokee lake from November 2013 through November 2014.

Age frequency

Carp in Cherokee lake ranged from 1^+ to 51 years old, Figure 5. The distribution is multi-modal showing irregular and inconsistent recruitment events. Carp demonstrated consistent and above average recruitment through the 1970's. Recruitment in the decade from 1982 through 1992 was more modest followed by only 1 strong year class in 1997. Small year classes appear annually from 2001 through 2004 followed thereafter with another 5 year absence in recruitment. Strong recruitment occurs in 2011 and 2012.

Growth

Von Bertalanffy growth curves were modeled from both dorsal spine and otolith derived ages. Age estimates from spines compared to otoliths were poorly correlated ($y= 0.2042X + 3.8858$: $R^2 = 0.3062$) . Spine ages grossly underestimated otolith ages, Figure 6. This study references the otolith-based Von Bertalanffy growth model, Figure 7. The model operated under the assumption of $K = 0.1$, and length at $t_0= 7.58$ inches. Carp attain an average length of 15.44 inches in their second year of growth. The asymptotic mean length was 25.76 inches. The length at infinity (L_∞) was 32.5 inches. Differing growth due to gender was not separated in this analysis. The fit of the model to the observed data suggests adequate accuracy ($y=0.1767x+19.125$: $R^2 = 0.7150$).

Summary and Recommendations

The project was successful in the confident estimation of the carp population in Cherokee lake, evidenced by a low CV and basic assumptions met (eg: tag loss, fin clip detection, vulnerability to capture, mortality, and mixing.

The length-weight regression allows for better weight estimation of longer fish which were under-represented in the weight subsample. There is strong agreement between observed and predicted weights which allows confidence in the estimate of biomass. Thus, we have some confidence in estimating the scale of the carp problem. This knowledge can help set contract fishing performance measures.

The aging data shows a carp population that has irregular recruitment. Growth into vulnerable sizes occurs by the second year of life. These life history considerations may allow for timely and targeted fishing control. Additional review of the hydrographic record to examine if observed recruitment events may correspond to stage or specific environmental conditions would be valuable. While many factors may dictate carp abundance, water level manipulation and exclusion from access into spawning habitat in concert with commercial removal are control strategies worthy of review.

Contract removal has demonstrated effectiveness. The volume of market sized desirable fish, including buffalo, appear sufficient to attract effort without incentive. Fishing is contracted to continue through 2015. A minimum effort and performance standard could be required by contract to increase exploitation from the current approximate 20% to a level where recruitment overfishing might occur. However, additional research may be necessary to accurately estimate fishing mortality required to reach recruitment overfishing.

Contract harvest occurred again in 2014 and included 32,900 lbs. of carp and 10,200 lbs. of buffalo. When 2014 harvest is subtracted from the 2013 biomass estimate, a total of 77,400 lbs. of carp were removed from Cherokee lake, representing 19.3 % of total biomass. This assumes no further increases to the estimated fall 2013 population from recruitment into the population from growth or immigration and no losses from natural mortality. These assumptions are obviously false because we know that fish below capture size in fall 2013 may have well grown into capture size in 2014, thereby adding to the estimated population. In an open system like Cherokee Lake , fish undoubtedly entered and left the system as observed by Wells (MS thesis 2013) in his estimation of fish movement through the Hwy 113 bridge narrows. Natural mortality in carp is low but some losses from the population occur. Given the variability and uncertainty in these rates, it is none-the-less necessary to have a gross idea of stock in order to develop management alternatives and choices.

The cost to partnering public agencies to incentivize and mobilize the contract fisherman to accomplish the netting component of this project was $5615 DNR and $2500 Dane county for a total of $8115 or $ 0.85 per individual fish removed. By weight, the price per pound of removal was $0.18/lb. A similar effort in 2008 in Lake Wingra (Liebl, 2008, unpublished) estimated the price per pound of removed fish at $0.07 or $0.63 per individual

With these metrics in hand, we now have a more certain understanding of the use, effect, and cost of contract fishing as a primary control tool. Given the current focus on phosphorus reduction to meet water quality goals the removal of carp warrants evaluation as a strategy to control P re-suspension and delivery.

Phosphorus in sediments is re-suspended by precipitation events, wind, and bio-turbation by carp.

Wells (2013) estimated the carp induced re-suspension of phosphorus in Cherokee lake to be from 5% to 16% of the total available to mobilization. The Cherokee Lake- Yahara estuary is believed to contribute approximately 30,000 pounds of P annually to downstream Lake Mendota as measured at the HWY 113 gauge. Adopting the most liberal estimate of bio-turbation of 16%, carp re-suspended 4,800 pounds of P.

Wu (pers.comm.) reported resuspension rates from carp measured in Lake Wingra to be 0.153 g/day of total phosphorus per kg of fish from enclosure experiments. . Assuming that sediments in Lake Cherokee are similar to those of Lake Wingra, the carp biomass present in 2013 would re-suspend 22,270 pounds of phosphorus annually.

Thus, carp as an engine for phosphorus re-suspension and delivery contribute between 4800 pounds and 22,270 pounds of phosphorus to downstream Lake Mendota annually.

Contract fishing efforts removed 19% of the estimated biomass (77,400 pounds of an estimated 400,758 pounds). Thus, 912 pounds to 4231 pounds of phosphorus loading from carp may have been negated from one contract fishing event. This represents a 3% to 14% reduction in the total P budget of Cherokee lake. The corresponding price per pound of phosphorus negated was $1.91to $8.89. Encouraging gains in water quality in Lake Wingra were realized after similar efforts in 2008. Carp removal may represent an affordable water quality strategy.

More aggressive removal efforts that reduce biomass by 50% or more could result in a total P reduction of 12% to Lake Mendota. Coarse estimates of cost to contract a removal at such scale suggest a price of $4.50 per pound of P left undisturbed by carp. These sediments could be dredged to remove phosphorus from delivery to the Yahara lakes.

Carp control and removal represent a tool in meeting habitat, fishery and water quality goals.

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Wu, Dr. Chin-Hesian. Dept. of Civil and Environmental Engineering , University of Wisconsin, Madison . Personal communication

Figure 1. Locations of radio telemetered carp, Lake Cherokee, Feb 26, 2012

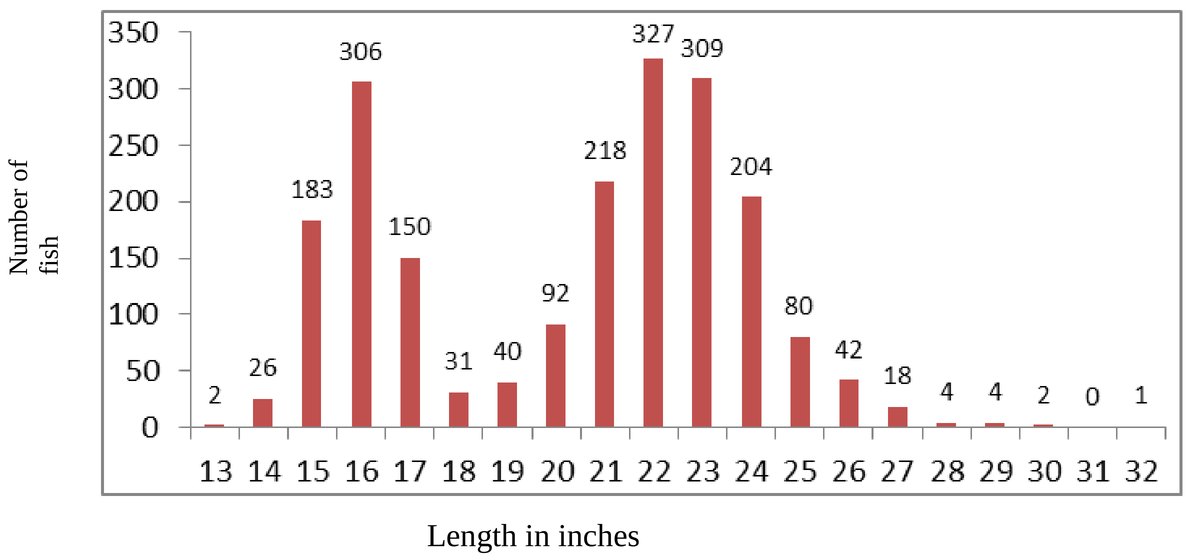

Figure 2. Length frequency distribution of carp from Lake Cherokee, sampled by seining, November 2013.

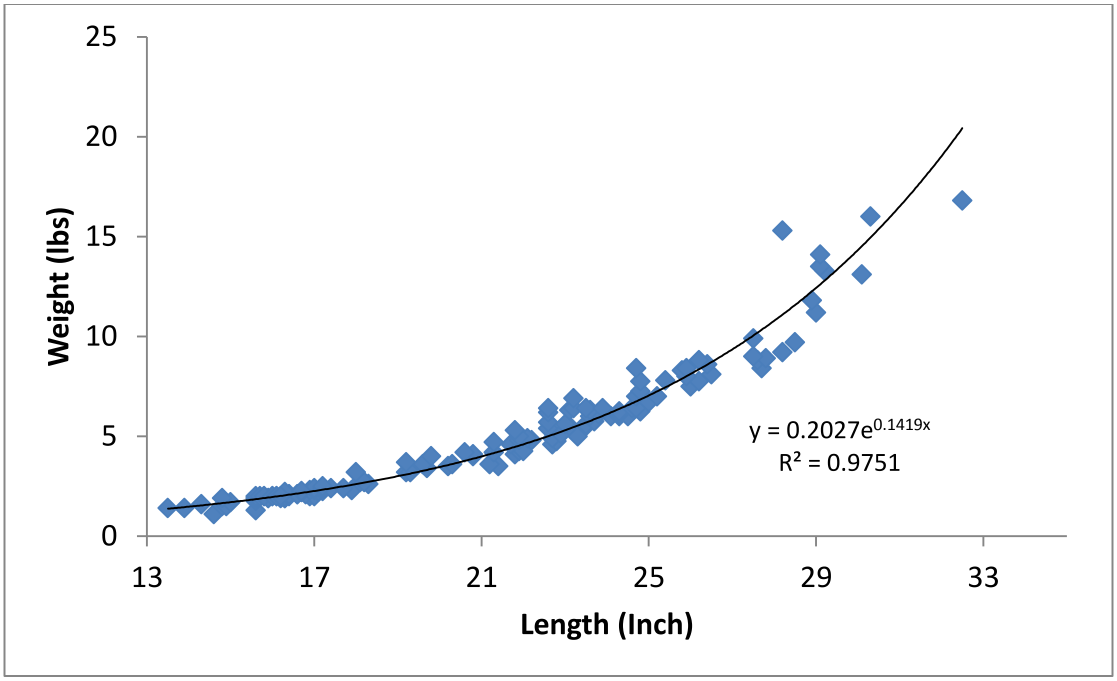

Figure 3. Observed Length-Weight relationship of carp, Lake Cherokee, November 2013.

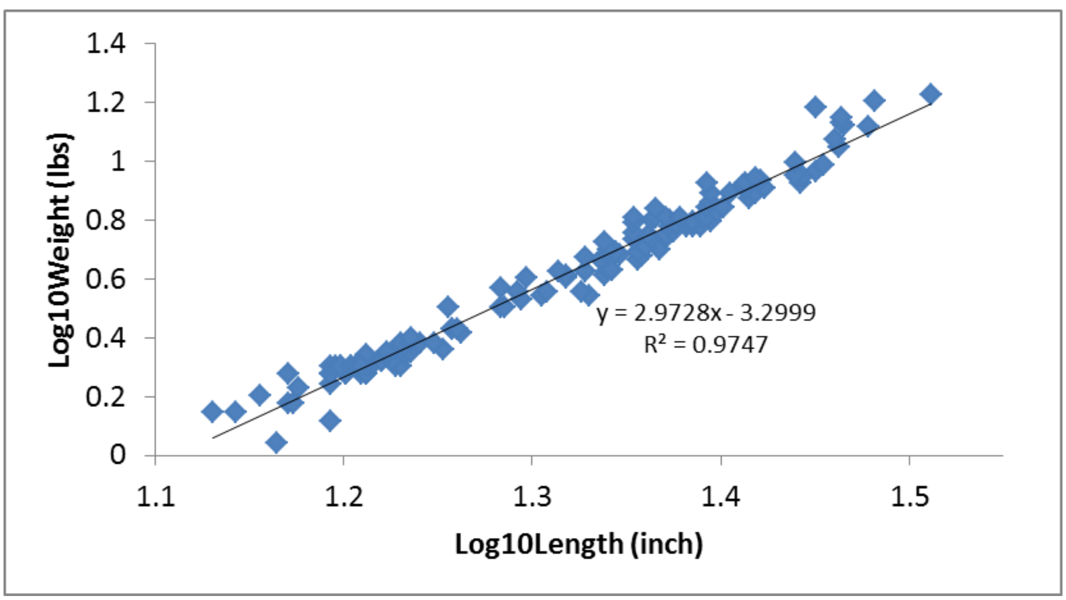

Figure 4. Log transformed length-weight relationship of carp, Lake Cherokee, November 2013, with predicted regression model .

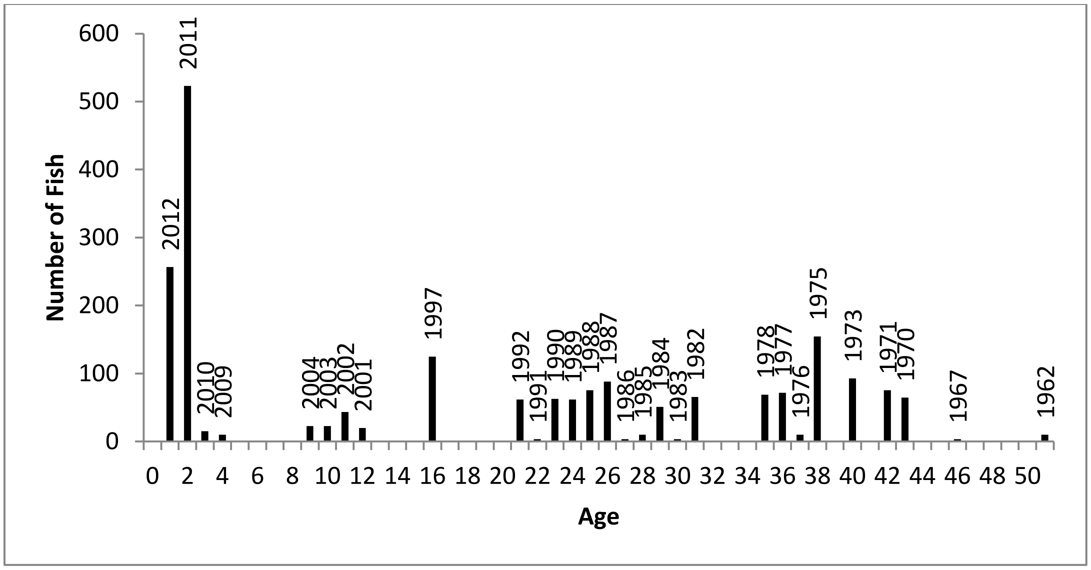

Figure 5. Age frequency graph illustrating the distribution, number of fish of a given age, and corresponding year of recruitment. From aged sub-sample (n=83) of Cherokee Lake common carp.

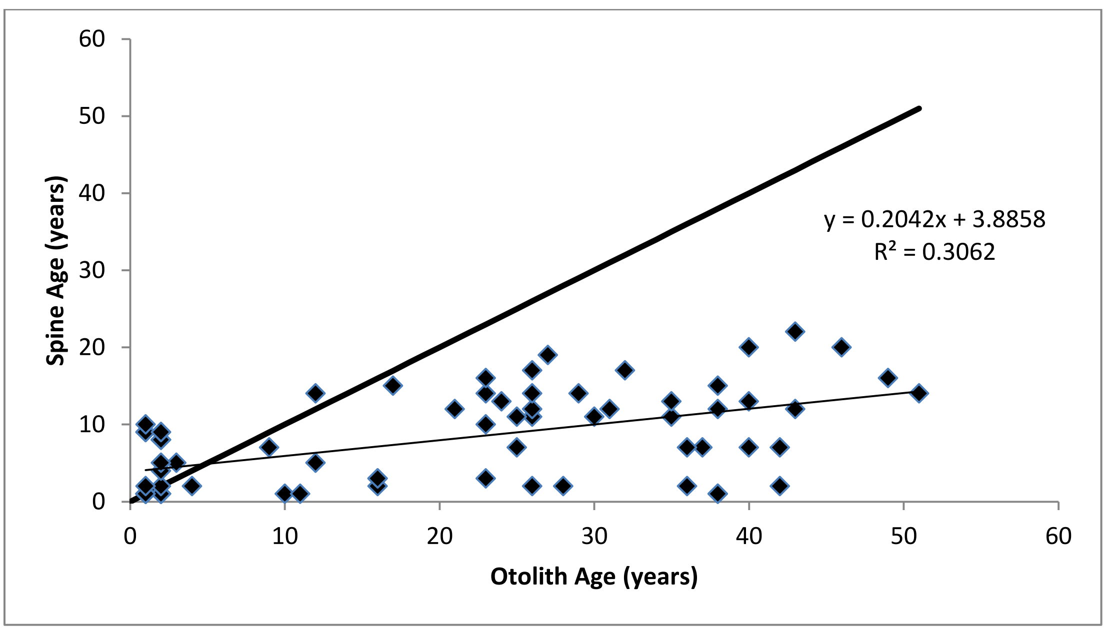

Figure 6. Linear comparison of otolith age to spine age for the aged sub-sample of Cherokee Lake common carp.

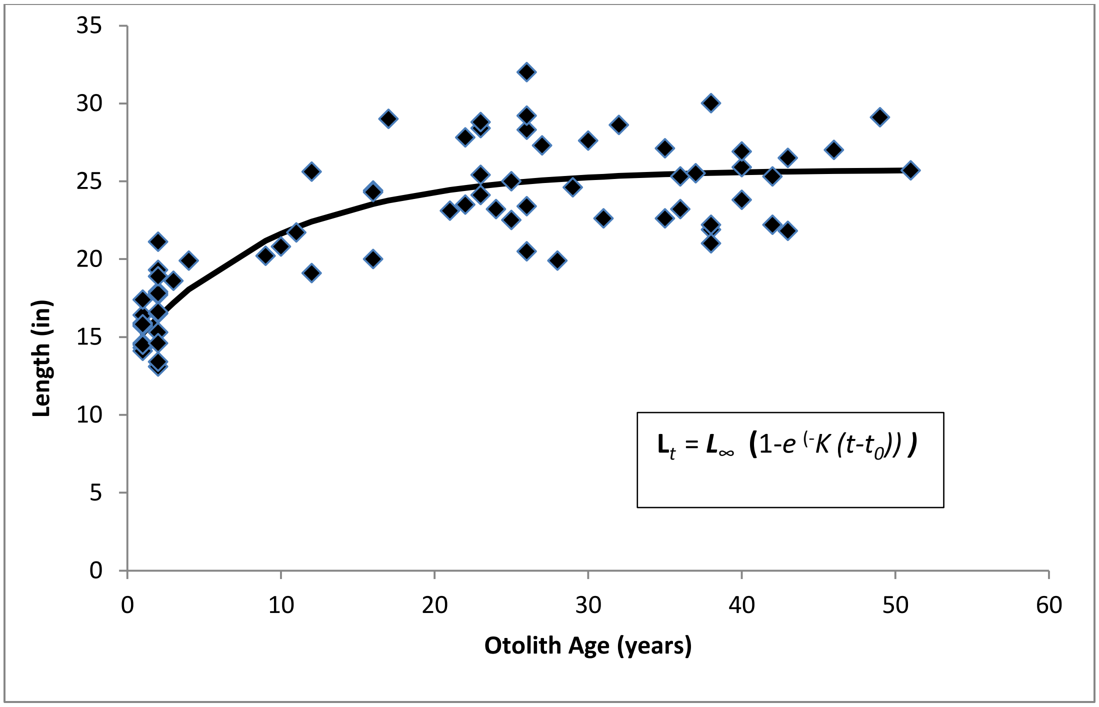

Figure 7. Von Bertalanffy growth curve representing otolith age (years) in correlation to fish growth (inches) of common carp from Cherokee Lake.

Date	Population (estimated)	Harvest	Biomass
November 1, 2013	90,000		400,000 lbs.
November 22, 2013		9955 # 44,500 lbs	355,500 lbs.
May 2014		447 # 2000 lbs	353,500
July 2014		201 # 900 lbs	352,600
October 2014	90,000 - 17,315 +/-	6711# 30,000	322,600 + / -

Table 1. Cherokee lake carp harvest and related population and biomass index, November 2013 through October 2014.